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DESCRIPTION

SURFACE ACOUSTIC WAVE FILTER AND DEVICE USING THE SAME

TECHNICAL FIELD

The present invention relates to a surface acoustic wave filter used in a communication device and a device using the filter.

BACKGROUND ART

Fig. 15 shows conventional ladder type surface acoustic wave (SAW) filter 1001 disclosed in Japanese Patent Laid-Open Publication No.6-152317. Series resonators 23, 24, 25 and 26 are connected between input terminal 21 and output terminal 22 in series in this order from input terminal 21 to output terminal 22. One end of parallel resonator 27 is connected with a point between series resonators 23 and 24. One end of parallel resonator 28 is connected with a point between series resonators 25 and 26. Other end of parallel resonator 27 is connected with a ground via inductance element 29 providing an inductance. Other end of parallel resonator 28 is connected with a ground via inductance element 30 providing an inductance.

SAW filter 1001 has characteristics denoted by line 202 in Figs 2 and 3. As shown by line 202, SAW filter 1001 has attenuation bands at both sides of a pass band. The filter, such as SAW filter 1001, is required to have characteristics reducing a loss in the pass band and shifting sharply to the attenuation bands.

SUMMARY OF THE INVENTION

A surface acoustic wave (SAW) filter includes a first SAW resonator, a

ATTACHMENT B

second SAW resonator connected in series to the first SAW resonator at a first node, a third SAW resonator connected in series to the second SAW resonator at a second node, a fourth SAW resonator connected in series to the third SAW resonator at a third node, a fifth SAW resonator connected between the first node and a ground, a sixth SAW resonator connected between the third node and a ground, and a first capacitance element having a capacitance and connected between the second node and a ground.

This SAW filter has a sharp attenuation characteristic at a high frequency area of a pass band, thereby widening the pass band and reducing a loss at the pass band.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram of a surface acoustic wave (SAW) filter in accordance with an exemplary embodiment of the present invention.

Fig. 2 shows frequency characteristics of the SAW filter in accordance with the embodiment.

Fig. 3 shows frequency characteristics of the SAW filter in accordance with the embodiment.

Fig. 4 is a sectional view of the SAW filter in accordance with the embodiment.

Fig. 5 shows an equivalent circuit of the SAW filter in accordance with the embodiment.

Fig. 6 shows an equivalent circuit of the SAW filter in accordance with the embodiment.

Fig. 7 is a plan view of the SAW filter in accordance with the embodiment.

Fig. 8 is a plan view of a capacitance element of the SAW filter in

accordance with the embodiment.

Fig. 9 is a plan view of another capacitance element of the SAW filter in accordance with the embodiment.

Fig. 10 is a plan view of a further capacitance element of the SAW filter in accordance with the embodiment.

Fig. 11 is a plan view of another SAW filter in accordance with the embodiment.

Fig. 12 is a plan view of a further SAW filter in accordance with the embodiment.

Fig. 13 is a circuit diagram of a still further SAW filter in accordance with the embodiment.

Fig. 14 is a block diagram of a device including the SAW filter in accordance with the embodiment.

Fig. 15 is a circuit diagram of a conventional SAW filter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 is a circuit diagram of surface acoustic wave (SAW) filter 101 in accordance with an exemplary embodiment of the present invention. Series resonators 3-6 are connected in series in this order from input terminal 1 to output terminal 2 between input terminal 1 and output terminal 2. One end of parallel resonator 7 is connected to a node between series resonators 3 and 4. One end of parallel resonator 8 is connected to a node between series resonators 5 and 6. Other end of parallel resonator 7 is connected with a ground via inductance element 9 having an inductance. Other end of parallel resonator 8 is connected with a ground via inductance element 10 having an inductance. Capacitance element 11 having a capacitance is connected between a ground and series resonators 4 and 5.

Figs. 2 and 3 show frequency characteristics of SAW filter 101 in accordance with the embodiment.

As shown by line 201 in Fig. 2, SAW filter 101 of the embodiment has a loss at a pass band from 1.92GHz to 1.98GHz less than a loss (shown by line 202) of conventional SAW filter 1001 shown in Fig. 15. SAW filter 101 has an attenuation at both sides of the pass band more than a attenuation (shown by line 202) of conventional SAW filter 1001, and the attenuation of SAW filter 101 is sharper than the attenuation (shown by line 202) of SAW filter 1001. SAW filter 101 of the embodiment has a larger bandwidth and a small loss than conventional SAW filter 1001.

Fig. 4 is a sectional view of SAW filter 101 in accordance with the embodiment. Inductance elements 9 and 10 are formed of wires connected with piezoelectric board 51 having resonators 3-8 provided thereon. Fig. 5 is an equivalent circuit of a portion of SAW filter 101 shown in Fig. 1. In general, respective self parallel resonances of series resonators 3-6 greatly contribute to attenuation at high frequencies in of the pass band of SAW filter 101. Additionally, in general, respective self series resonances of parallel resonators 7 and 8 greatly contribute to attenuation at low frequencies in the pass band of SAW filter 101. In general, respective self series resonances of series resonators 3-6 and respective parallel resonances of parallel resonators 7 and 8 greatly contribute to characteristics in the pass band of SAW filter 101. Attenuation characteristic has been conventionally designed by controlling these resonators. A ratio of the series resonance to the parallel resonance is determined substantially by conditions of the piezoelectric board having these resonators thereon.

Fig. 6 is an equivalent circuit around an attenuation pole at high frequencies of SAW filter 101 having the equivalent circuit shown in Fig. 5.

In this equivalent circuit, series resonators 4 and 5 correspond to parallel resonant circuits 12 and 13, respectively, and parallel resonators 7 and 8 correspond to capacitors 14 and 15, respectively. The equivalent circuit including capacitance element 11 shown in Fig. 6 is approximated to an elliptic function type band-pass filter around the attenuation pole at high frequencies.

As a result, SAW filter 101 has a large, sharp attenuation at high frequencies, thus having a wide bandwidth and a small loss, as shown by line 201 in Fig. 3.

For example, the capacitance of capacitance element 11 is determined to be 0.1pF, and series resonators 3-6 and parallel resonators 7 and 8 are designed appropriately, thus reducing a loss in the pass band (from 1.92GHz to 1.98GHz) from -0.9dB (shown by line 202) to -0.8dB (shown by line 201), as shown in Fig. 3.

Capacitance element 11 may be formed on the piezoelectric board similarly to series resonators 3-6 and parallel resonators 7 and 8. A method of the forming will be described.

Fig. 7 is a plan view of SAW filter 101 in accordance with the embodiment. Input terminal 1, output terminal 2, series resonators 3-6, parallel resonators 7 and 8, ground electrodes 16-18 and capacitance element 11 are formed on piezoelectric board 51. Capacitance element 11 is composed of interdigital electrodes 141 extending from ground electrode 18 and node 52 between series resonators 4 and 5, respectively, and facing each other.

Figs. 8-10 are plan views of other capacitance elements 111-113. In capacitance element 111 shown in Fig. 8, portions 111C and 111D protrude from respective long sides of electrodes 111A and 111B, respectively.

Electrode 111A extends from node 52 between series resonators 4 and 5. Electrode 111B extends from ground electrode 18 and face electrode 111A. In capacitance element 112 shown in Fig. 9, electrodes 112C and 112D protrude from electrodes 112A and 112B, respectively, and extend in parallel to each other. Electrode 112A extends from node 52 between series resonators 4 and 5. Electrode 112B extends from ground electrode 18. In capacitance element 113 shown in Fig. 10, toothed portions 113C and 113D are formed at electrodes 113A and 113B. Electrode 113A extends from node 52 between series resonators 4 and 5. Electrode 113B extends from ground electrode 18 and face electrode 113A.

Fig. 11 is a plan view of another SAW filter 102 in accordance with the embodiment. Interdigital electrodes 142, differently interdigital electrodes 11 forming capacitance element 141 shown in Fig. 10, are formed perpendicularly to series resonators 3-6 and parallel resonators 7 and 8. The number of fingers and intervals of interdigital electrodes 141 and 142 are determined by the capacitances. Since directions of interdigital electrodes 142 is different from directions of interdigital electrodes of the resonators by 90 degrees, interdigital electrodes 142 do not resonate with surface acoustic waves of the resonators. As a result, vibrations of the resonators do not influence capacitance element 11 regardless of the capacitance of capacitance element 11.

Fig. 12 is a plan view of further SAW filter 103 in accordance with the embodiment. Ground electrodes 16-18 are connected with ground electrode 40 surrounding elements of SAW filter 103 on piezoelectric board 51. This structure prevents the electrodes from breaking due to short-circuit between the electrodes caused by electric charges accumulating at piezoelectric board 51 during forming of the elements on piezoelectric board 51. Ground

electrode 40 functions as a mark when a wafer of a piezoelectric board having plural SAW filters formed thereon is divided into the SAW filters. After the wafer is divided into the SAW filters, ground electrode 40 is eliminated, thereby not influencing characteristics of SAW filter 103.

Fig. 13 is a circuit diagram of SAW filter 104 in accordance with the embodiment. Capacitance element 19 is connected between a ground and node 61 between series resonators 4 and 5. Capacitance element 20 is connected between a ground and node 62 between series resonators 5 and 6. In SAW filter 104, parallel resonators 7 and 8 forming an equivalent elliptic function band-pass filter may be designed flexibly at high frequencies of an attenuation band. Capacitance elements 19 and 20 may have the same structure as capacitance element 11 shown in Figs. 7-12.

Fig. 14 is a block diagram of a device including SAW filters 101-104 and other elements, such as antenna 41 and amplifiers 43 and 44, in accordance with the embodiment. Duplexer 42 including the SAW filter connected with antenna 41 is connected with power amplifier 43 for sending and power amplifier 44 for receiving. The device shown in Fig. 14 may be a portable telephone including rechargeable battery 145 for supplying electric power to duplexer 42 and amplifiers 43 and 44. For example, in the cases that battery capacity W of battery 145 is 580mAh, an effect of reduction of a loss at the pass band of the SAW filter by 0.1dB will be described.

Efficiency η(%) of the portable telephone is calculated by the following equation:

$$\eta=10^{(Pout/10)}/(1000\times V\times I)\times 100$$

where a voltage of battery 145 is V(V), a consumption current is I(A), and an output voltage of radio wave from antenna 41 is Pout(dBm).

In the case that the voltage V=3(V) and the efficiency η=40(%) are

constant, when Pout is 33(dBm), the consumption current of battery 145 is reduced by approximately 38.73(mA) from that of Pout of 33.1(dBm). If the portable telephone makes a call for 120 minutes with battery 145, a duration T of call in tha case that the consumption current is reduced by 38.73(mA) is expressed as the following equation:

$$T = 120\times(580+38.73)/580 \approx 128$$

Thus, when a loss at the pass band of the SAW filter is reduced by 0.1dB, the duration of call of the portable telephone increases by eight minutes.

INDUSTRIAL APPLICABILITY

A surface acoustic wave (SAW) filter of the present invention has sharp attenuation characteristics at high frequencies in a pass band, thereby having a wide pass band and a small loss at the pass band.